Title of Investigation:

Nanometer-Precision Alignment and Integration Method for X-ray Telescopes

Principal Investigator:

Dr. William Zhang (Code 662)

Other In-house Members of Team:

Jeffrey Stewart (Code 543) and Timo Saha (Code 551)

Other External Collaborators:

Dr. John Lehan (Universities Space Research Association) Dr. Kai-Wing Chan (Universities Space Research Association), and Bobby Nanan (Swales)

Initiation Year:

FY 2005

Aggregate Amount of Funding Authorized in FY 2005 and Earlier Years:

$37,200

Funding Authorized for FY 2006:

$0

Actual or Expected Expenditure of FY 2005 Funding:

Contracts: $14,000 to Rodriguez Precision Optics, Inc.; $22,400 to QED Technologies, Inc.; $800 for small purchases

Status of Investigation at End of FY 2005:

Transition to NASA ROSES/Astronomy and Physics Research and Analysis

Expected Completion Date:

September 2008

DDF annual report

Purpose of Investigation:

The goal of this investigation is to develop a precision technique for integrating next-generation X-ray telescopes. A key part of this investigation is determining the feasibility of fabricating various components needed for the integration process. Figure 1 is an illustration of an entire X-ray mirror integration process. The effort reported here is concerned with the mirror sheet (1), the spacer sheet (3), the alignment core (10) and the wagon wheel (9), where the numbers in parentheses correspond to the label in the Figure.

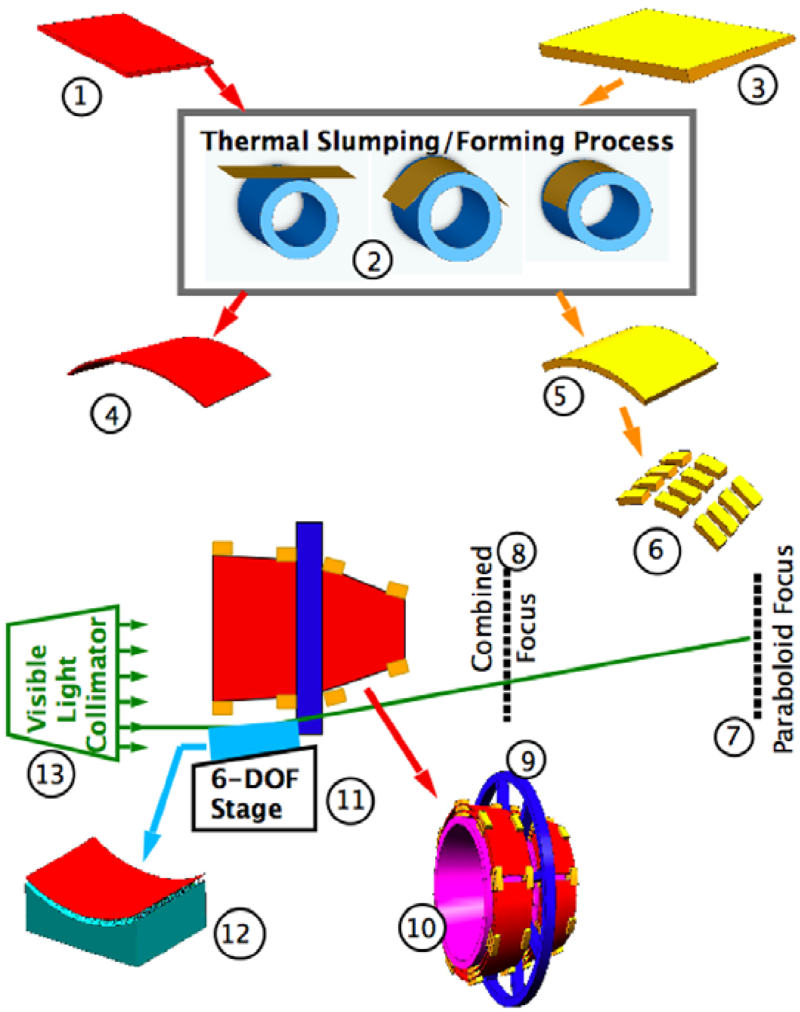

Figure 1. An illustration of the mirror-integration process. The effort reported here is concerned with the mirror sheet (1), the spacer sheet (3), the alignment core (10) and the wagon wheel (9).

Accomplishments to Date:

Mirror Sheet:

We contracted QED Technologies, Inc., of Rochester, NY, to figure 12 pieces of Schott D263 glass, each of which is 100 mm by 100 mm in size and 0.4 mm in thickness. These glass sheets vary in thickness on the order of 2 to 3 μm RMS. The integration requirement is for the glass thickness to be uniform within 20 nm RMS; in other words, the glass sheets need to undergo a factor-of-100 improvement in thickness uniformity. QED has demonstrated that its magneto-rheological figuring (MRF) technology can improve the thickness uniformity by a factor of 5 to 8. We have concluded from the data we have received so far that three polishing cycles are needed to bring the commercially available glass sheets up to requirement.

Spacer Sheet:

The spacer sheet is a wedge glass sheet, with a typical wedge angle of 0.5°. Starting with a sheet of more or less uniform thickness, a lot of materials need to be removed to create this wedge angle because such standard polishing technology does not work. We contacted RAPT Industries, Inc., of Livermore, California, to see whether its reactive atomic plasma figuring technology can be used to meet our needs. Our initial test pieces indicate that the company's material-removal rates can be an order-of-magnitude higher than the conventional polishing technique. We are in the process of issuing a contract (using funds other than the DDF) for them to make six wedges.

Alignment Core:

Code 551 (Carl Strojny) has successfully diamond-turned an aluminum alignment core, consisting of a primary and a secondary cone that had been precisely bolted together. The quality of these conical cores has a figure error of several arc-seconds, exceeding our requirements.

Wagon Wheel:

This component has been fabricated at the Goddard machine shop by Chris Kolos (Code 547). It meets requirements.

Planned Future Work:

One important part we have yet to address is the application of epoxy. Epoxy is needed to bind together the mirrors, spacers, and alignment core. Their uniform application is essential to achieve 50-nm integration precision, which is our goal. We will investigate at least two different techniques: (1) spraying, and (2) sputtering. We expect this work to be completed in FY 2006.

Once the epoxy application technique is in hand, we will integrate 24 mirrors with the alignment core. Then we will perform an X-ray test to verify the alignment precision.

Key Points Summary:

We have set out to demonstrate that we can align X-ray mirrors to a precision of 50 nm, using various commercially available fabrication techniques. When successful, this alignment technique will enable future space science missions with small, but high-angular resolution X-ray telescopes. Our goal is to reach 10-arcsecond-angular resolution in the next 2 years, and 5 arcseconds within 5 years, with a long-term goal of 1 arcseconds. Technical risks in our approach are mainly in achieving the final alignment precision. There are a number of factors that all need to work out right for us to reach 50 nm RMS.